PROCESS-STRUCTURE-PROPERTY RELATIONSHIPS OF ADDITIVELY MANUFACTURED MODEL SANDSTONE

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The additive manufacturing of sand-based composites has primarily seen applications in the metal casting industry to offer improved ability to prepare complex molds. The weak bonding between sand grains, afforded by a thermosetting polymer, offers easy mold knock-out and sand recycling (see Figure 1). Our work involves rethinking binder-jetting technology in order to re-task the end application – making model sandstone to perform geotechnical analysis of rock formations. A major goal of the work is to be able to quantify the material properties of the binder phase (a thermosetting acid-catalyzed polymeric resin) which can then be input into particle flow code simulations to predict geomechanical responses of rock formations. The additive manufacturing process, its limitations, and modifications we have made to improve mechanical response of composites will be explained in the context of performance relative to natural sandstone. In particular, we will demonstrate that failure analysis of fractured composites and identification of failure modes led us to innovate the use of silane coupling agents to improve adhesion, and resulted in a two-fold improvement in unconfined compressive strength. In addition, we will detail our efforts to measure elastic moduli of binder necks between individual sand grains, and model the stiffness parameters required for use in computer simulations for macroscopic mechanical responses. With this work, the aim is to be able to representatively print model sandstone in large statistical sample sizes to study fluid flow through simulated formations, effects of defects on mechanical and fluid flow behavior, and predict behavior knowing material properties of the constituent materials.

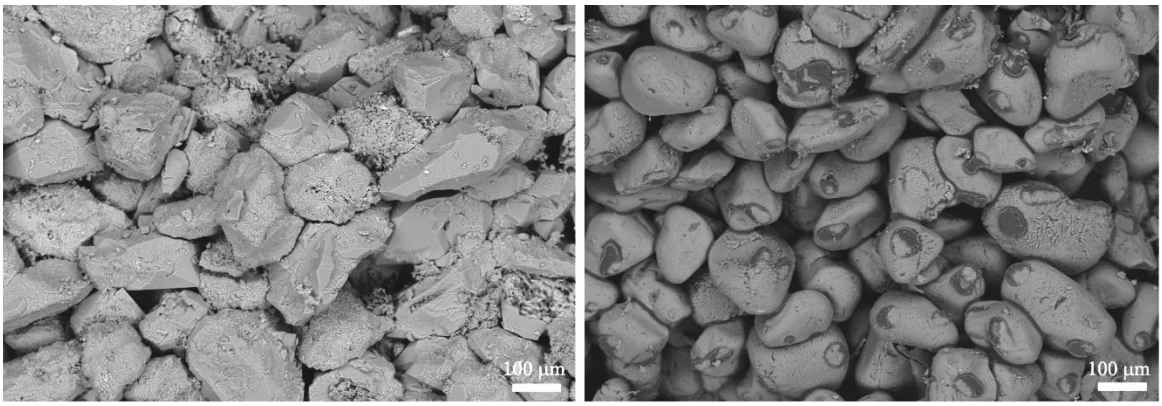

Figure1. Secondary electron SEM micrographs of fracture surfaces for natural Berea sandstone (left) and additively manufactured model sandstone (right). Particle shape and interstitial space are obvious differences between the two materials. Dark regions on the grains of sand on the model sandstone (at right) are polymeric binder residue.